THE REACTIONS OF THE BLIND FISH, AMBLYOPSIS SPELÆUS, TO LIGHT.[1]

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INTRODUCTION.

In the Woods Hole Biological Lectures ('99) Dr. Eigenmann gave the results of some experiments to determine the reaction of *Amblyopsis* to light. He recorded that:

1. *Amblyopsis* seeks the dark regardless of the direction of the rays.

2. An individual coming from a dark chamber into a lighted one shows signs of uneasiness.

3. A light ray thrown on fishes from a mirror causes uneasiness in from one to five seconds.

4. Bright sunlight causes the fishes to swim uneasily.

5. A lighted match held above an aquarium, which had been in the dark, caused two fishes in one instance to dart to the bottom. In another case it produced a very general and active movement among forty individuals.

6. Different colors do not cause different reactions.

7. In an open pool, the fishes remained under rocks during the bright part of the day.

It is the purpose of the present paper to repeat some of his experiments, but in a different way; to add others, to give data in full of how the fishes react and to determine why they react. The special interest in the problem lies in the fact that we are dealing with a blind animal, whose remote ancestors possessed well-developed eyes.

Part of the work was done at the Indiana University cave farm at Mitchell, Indiana; the remainder at the university. All the material used was caught in the caves at Mitchell.

These fishes are very sensitive to mechanical stimuli and with this in mind every possible precaution has been used to eliminate them. At Mitchell the cave was used as a laboratory and the

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aquarium placed on the solid earth, so no better nor more natural conditions could have been found. At the university, the experiments were made in a basement dark-room with black walls, where the temperature remained practically constant. The aquarium was set on a stone pedestal.

Only very simple experiments were made and conclusions have not been reached until after an examination of more than one series of fishes, although the data of only one series will be given.

Apparatus.

My apparatus consisted of an aquarium, a light screen, a heat screen and a lamp. The aquarium was 18 inches long, 15 inches high and 12 inches wide. The light screen was made of heavy cardboard and was placed between the end of the aquarium and the heat screen, so as to shut out all light except that entering from one end of the aquarium. A small aquarium was used for a heat screen. Its sides were of clear glass, parallel and placed 3 inches apart. This screen was placed 2¼ inches from the end of the aquarium. The water used in both the aquarium and heat screen was filtered. Two lamps were used, one an acetylene lamp of one hundred candle power, and the other an arc lamp of eight hundred candle power.

Experiments and Observations.

My experiments at Mitchell were made with the hundred candle power lamp. First, the lamp was placed 32 inches from the end of the aquarium and with it in this position the whole aquarium was lighted. As the aquarium was 18 inches in length there was considerable difference in the intensity of the light at the two ends. With ten fishes, ranging from 2½ to 4 inches in length in the aquarium, counts were taken once a minute for thirty minutes, and at the end of this time the counts showed 163 fishes in the end of less, and 137 in the end of greater intensity. Before making this observation and with the aquarium lighted just enough to enable me to see the fishes as white objects, I took counts to see whether they showed any preference for one end of the aquarium over the other. Thirty-five counts gave me 176 fishes in one end and 174 in the other. So the large number of

fishes in the end of greater intensity could not have been due to a preference for that end.

With the light in the same position and with half of the aquarium darkened by means of a light screen, counts were again taken as before. First one half of the aquarium and then the other was made dark. Sometimes these counts showed more fishes in the dark; at others more in the light. Under natural conditions the fishes swim very slowly. During these observations their movements were much faster, thus indicating that they are photodynamic. All subsequent observations, whether the light was of a low or high intensity, brought out this fact very distinctly.

On account of the shape of the lamp, it could not be brought closer than 32 inches and still illuminate the whole aquarium. I therefore made a small aquarium, 7 inches long, 5 inches high and 4 inches wide, and suspended it within the larger. In this case the heat screen was removed as there was always three or four inches of water between the fishes and the lamp. With the lamp only nine inches from the end of the small aquarium and with half of the aquarium darkened in various ways, I took a large number of counts. These observations were made on three series of fishes. The results were again conflicting. In the majority of cases a larger, sometimes a much larger number of fishes were seen in the dark, but sometimes a larger number were observed in the light. The fishes seem to be disturbed more with the light at this distance than when it is 32 inches from the end of the aquarium.

At the university an 800 candle power arc lamp was used. The heat and light screens were again placed in position and during the observations the entire aquarium, except the end where the light entered, was covered with heavy black cloth. The fishes were transferred from the cave to the aquarium in a closed vessel and hence were not exposed to the light. They were left in the aquarium, at least twenty-four hours before observations were made, so they could become accustomed to the new conditions. Also after taking one series of counts they were left several hours before making other observations. With the lamp 16 inches from the end of the aquarium, counts were taken every

minute for thirty minutes and with ten fishes in the aquarium. First the right half was darkened. These counts gave me 84 fishes in the light to 216 in the dark. I then lighted the whole aquarium to see whether they would seek the end away from the light, *i. e.*, the end of less intensity. These counts gave me 85 fishes in the end of greater and 215 in the end of less intensity. Here is a difference of 130, while with the one hundred candle power lamp 32 inches from the end of the aquarium, there was a difference of only 26.

With the aquarium just sufficiently light for me to see the fishes, I took counts to see whether they remained at the surface or near the bottom. These counts showed 101 fishes in the upper half and 199 in the lower. This indicates that they are positively geotropic. To determine whether their positive geotropism would be overcome by their negative heliotropism, I darkened first the lower and then the upper half of the aquarium. With the lower half dark, the counts showed 56 fishes in the light to 244 in the dark and with the upper half dark 121 in the light to 179 in the dark. While their geotropic reaction is partly overcome by their negative heliotropism, it is not wholly so.

To determine whether the direction of the rays of light plays any part in the movements of the fishes, the light was placed 14 inches above the surface of the water. As no convenient heat screen was at hand, a clear glass which fitted snugly against all sides of the aquarium, was lowered 2½ inches beneath the surface. Thus there was always 2½ inches of water between the fishes and the light. With the lamp in this position, I darkened first one end and then the other and took counts as before. Thirty counts with the left end dark showed 68 fishes in the light and 232 in the dark, and with the right end dark 64 in the light and 236 in the dark. At the end of each count, I shifted the light screen to the opposite end, and each time the fishes within two or three minutes changed to the dark end again. This immediate change, with the shifting of the light, proves conclusively that the light is the only factor which caused them to seek the dark. These counts confirm the conclusion of Eigenmann that they seek the dark regardless of the direction of the rays.

With the light coming from above, we get a larger percentage

of fishes in the dark than when the light strikes them from the side. It is possible that with the light overhead, the brain and spinal cord are affected directly on account of the transparency of the tissue above them.

For comparison, I caught a number of small specimens ranging from 15 to 25 mm. in length, placed 10 of them in the aquarium and made observations as I had done with the adults. In these fishes, the eye was plainly visible as a small black spot beneath the skin, while in the adults there is no external indication of an eye. With the light at the end of the aquarium and the whole aquarium lighted, the thirty counts showed 115 fishes in the end of greater and 185 in the end of lesser intensity, as compared with 85 to 215 in the case of the adults. With the left half dark there were 60 in the light to 240 in the dark, as compared with 98 to 202 in the adults. With the right half dark, 48 in the light to 252 in the dark, against 84 to 216 adults. The light was then placed above the aquarium as before and counts taken. When the left end was dark there were 28 fishes in the light to 272 in the dark and with the right half dark there were 25 in the light to 275 in the dark, as compared with 68 to 232 and 64 to 236 in the case of the adults. Here again we have a larger percentage of fishes in the dark when the light is above, and, further, these young fishes seem to be more sensitive to the light than the adults. What is the reason for this? Thinking that the eye might play some part in this difference I removed the eyes from 10 young. Seven of these recovered in good condition. Of these I took five, all of which were about an inch in length, and 52 hours after the operation made the first observation.

With the light at the end and the left half dark, thirty counts gave me 19 fishes in the light to 131 in the dark, and with the right half dark, 22 in the light to 128 in the dark, as compared with 48 to 252 and 60 to 240 in the case of the young with eyes. These observations show that there is practically no difference in the reactions of the young with eyes and those without eyes. Hence the eyes play no part in the reaction.

In making these experiments the counts often varied considerably in the same series even though the external conditions, so

far as I was able to determine, were exactly the same. However, this is to be expected, since the fish is a highly complex organism and its internal mechanism is not the same at any two times.

To determine whether the skin is equally sensitive on all parts of the body, I used a light focused to a point by means of a Zeiss *a* * objective. With the aquarium dark, I focused this light on various parts of the body. Sometimes they reacted and sometimes they did not, but they reacted as often with the light focused on the tail as on the head, and *vice versa.* Later I placed some fishes in a dark corner of a room and with a mirror threw sunbeams on various parts of the body. In nearly every case I got a definite reaction. Sometimes the fishes turned around and swam in the opposite direction and sometimes darted forward. Further, they reacted as often when the light was thrown on the tail as on the head. Judging from these experiments they are equally sensitive on all parts of the body. However, this is what we might expect since all parts of the skin are exposed to like conditions. Parker ('05) concludes that the tail of Ammocœtes is most sensitive to light, but he accounts for this by the fact that Ammocœtes burrows head foremost into the sand.

Eigenmann ('99) states: "Two examples [of blind fishes] kept in a pail in my cellar were quietly floating, but when a lighted match was held above them, the fishes at once darted to the bottom and sides of the pail." This is not a common reaction. I have tried the lighted match again and again and also have flashed the one hundred candle power lamp above them, and in no case did they dart to the sides or bottom immediately. In fact, they did not react immediately when the eight hundred candle power lamp was flashed on them. With the fishes in their native habitat I have made a number of observations with the one hundred candle power lamp by flashing it upon them as they lay perfectly quiet in the water, and in each case it was from 10 to 30 seconds before any movement took place. In nearly all cases the movement was either to one side or straight ahead and not toward the bottom. My results are more in accord with his observation on forty individuals when a lighted match "produced a very general and active movement among all individuals."

In the same paper Eigenmann records the action of a colony of Amblyopsis in an open pool. "During the bright part of the day, the fishes always remain under the rocks at the bottom. In the morning and evening and at night they could be seen swimming about in various parts of the pool." At Mitchell, near the entrance of one of the caves, is a small pool, the bottom of which is covered with rocks. I found two fishes in this pool. They were probably washed there during times of high water, as the water runs from one cave to the other at such times. Later, I put two more fishes into the pool and as I was making daily trips to the cave I often noticed them swimming about near the surface. The pool was not in the direct sunlight but the sun reached it, in patches, between twelve and one o'clock, and I took a number of observations at this time. I watched the pool for 15 minutes at a time and out of 13 observations made on 13 different days was able to see from one to three fishes ten times out of the thirteen. Sometimes they came out only to go immediately back under the rocks, but they often remained at the surface from five to ten minutes. Apparently this seems to conflict with my former experiments, but such is not the case, because under no condition did the fishes remain in the dark all the time. I do not mean to say that in the pool the fishes remain in the light more than in the dark, but that they do come out at times even in the brightest part of the day.

Conclusions.

1. *Amblyopsis* is negatively phototropic.
2. The young are more sensitive to light than the adults.
3. The young deprived of eyes are as sensitive as those with eyes. Hence the eyes play no part in their reactions.
4. They seek the dark regardless of the direction of the rays.
5. When stimulated with a light focused to a point they seem to be equally sensitive on all parts of the body.
6. They are positively geotropic.
7. They are photodynamic.
8. These fishes are sensitive to light of low intensity and this sensitiveness increases as the intensity of the light increases.